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No. 5

ABUNDANCE AND DISTRIBUTION OF FISHES IN THE GALVESTON BAY SYSTEM, 1963–1964[1]

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ABSTRACT

The fish fauna inhabiting the Galveston Bay estuarine system was studied from January 1963 through December 1964. Ninety-six species and 364,815 individuals were collected by trawl. Dominant in the system was *Micropogonias undulatus* (51.2% by number, 36.5% by wet weight). Other numerically important fishes were: *Anchoa mitchilli*, 22.3%; *Stellifer lanceolatus*, 8.0%; *Leiostomus xanthurus*, 4.1%; *Cynoscion arenarius*, 3.3%; and *Arius felis*, 2.4%. In terms of biomass, other important species were: *L. xanthurus*, 9.1%; *Mugil cephalus*, 7.6%; *S. lanceolatus*, 6.5%; *A. felis*, 5.7%; and *C. arenarius*, 5.0%. Fishes were most abundant in the upper estuary, while the number of species recorded was highest in the shallow Gulf of Mexico just offshore from the estuary. *Stellifer lanceolatus* was the most abundant fish in the channel zones of the estuary and co-dominated with *C. arenarius* in Gulf waters. *Anchoa mitchilli* was the dominant fish in the waters of the main tidal pass. In all other zones (open, near shore, and peripheral waters) and bay subareas, *Micropogonias undulatus* was numerically dominant. The areas of maximum abundance for 59 species are also given. Mean number of fishes per tow was significantly higher in 1963 than in 1964, attributable mainly to larger catches of *A. mitchilli* and *S. lanceolatus* in several months of 1963. However, on an annual basis, mean fish biomass per tow was stable even though monthly differences were noted.

No other system-wide studies of the fish fauna of Galveston Bay have been conducted. Results of the few limited investigations conducted before or after 1963–1964 conflict with the results of the latter. Resultant differences might equally be attributed to natural fish population fluctuations, differences in sampling methodology, and rapid human development and use of the estuary and surrounding lands.

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INTRODUCTION

In January 1963, the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) initiated a large-scale, two-year survey of the fishes, invertebrates, and hydrology of the Galveston Bay estuarine system.

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The object of the study was to obtain baseline ecological information on the estuary before anticipated development of land and water resources altered the area. Initial results of this study were summarized in annual reports of the Galveston Laboratory (U.S. Fish and Wildlife Service, 1964, 1965). Since the end of the survey, various aspects of the study have been examined. Pullen and Trent (1969) tabulated all hydrographic data collected in the estuary from 1958 through 1967. Pullen, Trent and Adams (1971) analyzed the temperature, salinity, nitrogen, phosphorus, and dissolved oxygen data for the 1963–1966 period. The distribution and migration of brown shrimp *(Penaeus aztecus)* were discussed by Parker (1970), and Trent, Pullen, Adams and Zamora (1974) tabulated catch per unit of effort and size of *P. aztecus* collected in the estuary from 1963 through 1967.

The only publications concerning the fishes collected in the survey have been those by Parker in 1965 and 1971. The 1965 publication is a checklist of 162 fish species recorded in the bay by the Bureau of Commercial Fisheries and the then Texas Game and Fish Commission (now Texas Parks and Wildlife Department), and the 1971 publication is a comparative analysis of the biologies of spot *(Leiostomus xanthurus)* and croaker *(Micropogonias undulatus)* in Galveston Bay and Lake Borgne, Louisiana. Bechtel and Copeland (1970), who sampled fishes at 28 sites in the estuary on a quarterly basis, related diversity to pollution inputs. No other synoptic surveys have been conducted in the Galveston Bay estuary, but several environmental impact studies of limited areal extent have been made. Reid (1955 a, b, 1956, 1957) conducted trawl surveys in three successive Junes (1954–1956) in East Bay to document the effects of the opening of Rollover Pass on the fish and invertebrate faunas. Chambers and Sparks (1959) surveyed the trawlable organisms in the San Jacinto River and the Houston Ship Channel in connection with the opening of an oil refinery. Two studies of the fish faunas near power generating stations have been conducted, one on Cedar Bayou near the mouth of the San Jacinto River (Johnson 1973) and a second near Dickinson Bay (Gallaway and Strawn 1974). The fish fauna that inhabited a dredge spoil disposal site off the mouth of Bolivar Roads Tidal Pass was examined by Henningsen (1977).

In this report, the data concerning fishes collected in the 1963–1964 estuarine survey are historically significant because of the rapid development of the surrounding areas since the time of the survey, and because the data represent a baseline for current and future research on the estuary.

MATERIALS AND METHODS

Biological sampling and water temperature and salinity data were collected at up to 65 stations in the Galveston Bay estuary of Texas from January 1963 through December 1964 (Figure 1, Table 1). Latitudes and longitudes of all stations are given in Pullen and Trent (1969). The stations were grouped by zones and subareas. Zones included:

1) Channel—9 stations, 4 to 13-m depths (mean = 11 m);
2) Open water—27 stations, 1 to 13-m depths (mean = 3 m);
3) Shore—20 stations, 0.3 to 1-m depths (mean = 0.6 m), and
4) Peripheral lakes, lagoons, and bayous—9 stations, 0.6 to 2-m depths (mean = 1.0 m).

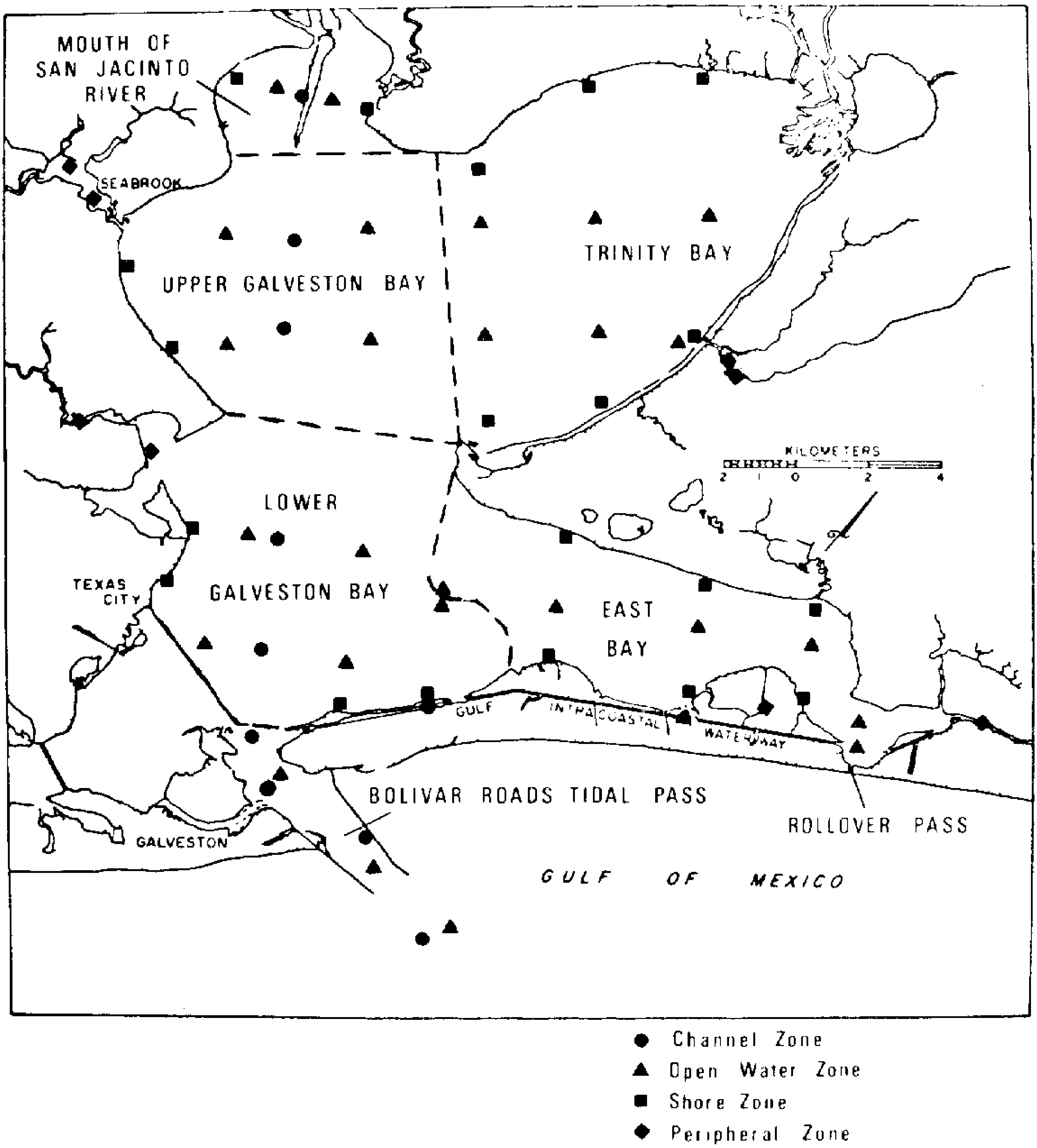

FIG. 1. The Galveston Bay system and locations of sampling stations by zones and subareas.

Subareas included: 1) Gulf of Mexico, 2) Bolivar Roads Tidal Pass, 3) Lower Galveston Bay, 4) Upper Galveston Bay, 5) Mouth of the San Jacinto River, 6) Trinity Bay, and 7) East Bay.

Data were collected twice monthly during daylight hours at each station from January 1963 through February 1964 and monthly from March through December 1964. Biological samples were collected with a 3-m otter trawl (35-mm mesh wing and body, 23-mm mesh cod end) towed for 5 minutes at about 2 knots. Fishes were returned to the laboratory where total number and wet weight were recorded for each species. Temperature and salinity were recorded from samples taken near the bottom with a Kemmerer bottle. Temperatures were measured with a stick thermometer, and salinities were measured either by Industrial Instruments Model RS-5 portable salinometer (mention of commercial products does not constitute endorsement by the U.S. Department of Commerce) or by titration of samples.

After the survey, the raw biological data were stored on computer cards which were then used to summarize the data. In the interval between data summarization and the present, the

TABLE 1

Numbers of trawls (T) and stations (N) made in various zones and subareas of Galveston Bay, 1963–1964. Zones included ship channel (C), open water (O), shore (S), and peripheral lakes, lagoons, and bayous (P). Subareas included Gulf of Mexico (GM), Bolivar Roads Tidal Pass (TP), Lower Galveston Bay (LG), Upper Galveston Bay (UG), Mouth of the San Jacinto River (MS), Trinity Bay (TB), and East Bay (EB). Station numbers are taken from Pullen and Trent (1969). Dash (–) indicated no sampling.

		Zones and Years											
		C		O		S		P		Totals		Grand	
Subarea		63	64	63	64	63	64	63	64	63	64	Total	Station Numbers
GM	T	24	14	23	14	-	-	-	-	47	28	75	1,2
	N	1		1		-		-		2			
TP	T	48	28	48	28	-	-	17	14	113	70	183	3-7
	N	2		2		-		1		5			
LG	T	72	42	118	70	93	56	48	27	331	195	526	9,16,17,24-27,32,33,35,36,38,44,46
	N	3		5		4		2		14			
UG	T	46	28	96	42	47	28	47	38	236	136	372	62-65,69,75,79,82,83,85
	N	2		4		2		2		10			
MS	T	24	14	45	28	47	28	-	-	116	70	186	95,97-100
	N	1		2		2		-		5			
TB	T	-	-	142	84	134	84	45	28	321	196	517	49-51,54,56,58,66,67,86-88,90,92,93
	N	-		6		6		2		14			
EB	T	-	-	166	98	139	84	45	28	350	210	560	11-13,18-20,22,23,28,29,31,39,40,42,43
	N	-		7		6		2		15			
Total	T	214	126	638	364	460	280	202	135				
Grand	T	340		1002		740		337		2419			
Total	N	9		27		20		9		65			

original data were lost. This prevented analyses of community indices such as species diversity, evenness, and similarities, for which original station data are necessary. The following sections thus deal only with summary data.

RESULTS AND DISCUSSION

THE FISH COMMUNITY

Ninety-six species of fishes were recorded among 364,815 individuals collected over the 24-month study period (Tables 2 & 3). Six species accounted for 91.3% of the total number of fishes collected: *Micropogonias undulatus,* 51.2% *Anchoa mitchilli,* 22.3%; *Stellifer lanceolatus,* 8.0%; *Leiostomus xanthurus,* 4.1%; *Cynoscion arenarius,* 3.3%; and *Arius felis,* 2.4%. *Micropogonias undulatus* was the dominant species during 14 winter through summer months, *Anchoa mitchilli* predominated during 8 fall and winter months, and *Stellifer lanceolatus* was the most abundant fish on two

TABLE 2

Monthly abundances of the 25 most numerous fishes collected in Galveston Bay in 1963 and 1964 and their distributions by zone and subarea over 24 months. Other information as in Table 1.

Temporal distribution:	1963											
Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Micropogonias undulatus	3125	4743	23310	36608	36309	12360	4685	1734	379	208	573	934
Anchoa mitchilli	1851	5498	3550	4332	6109	9960	2886	3382	4154	10220	5815	3308
Stellifer lanceolatus	16	1	6	52	130	1656	3202	16901	1013	914	683	201
Leiostomus xanthurus	150	110	153	918	1968	973	1309	752	294	156	75	401
Cynoscion arenarius	19	6	52	347	1165	862	951	1137	464	1236	393	151
Arius felis	10	1	21	34	39	38	285	3436	1457	1016	52	9
Sphoeroides parvus	45	1	61	70	283	717	750	974	470	196	248	263
Brevoortia patronus	149	225	1561	163	85	288	28	17	17	25	57	277
Symphurus plagiusa	102	242	224	132	188	228	103	165	173	206	300	404
Citharichthys spilopterus	9	19	8	113	1252	705	428	227	79	35	31	15
Polydactylus octonemus			4	87	598	517	150	38	8			
Menticirrhus americanus	42	35	299	18	107	69	55	40	89	70	54	280
Mugil cephalus	149	322	83	36	8	2	10	9	2	2	3	292
Bagre marinus					1	1	166	333	45	16		
Achirus lineatus	11			2		3	44	152	80	117	145	31
Prionotus tribulus	71	38	131	83	40	18	7	2		18	20	54
Etropus crossotus	19		16	11	4	4	42	53	74	36	58	70
Porichthys plectrodon			2	8	21	41	16	21	28	128	26	5
Paralichthys lethostigma	38	29	43	62	30	5	7	7	7	3	9	4
Urophycis floridanus	4	7	36	9								2
Bairdiella chrysoura	1	2	4	4	15	18	25	18	13	3	3	7
Chaetodipterus faber	1			1	2	4	8	19	29	24	10	7
Cyprinodon variegatus	67	17										13
Synodus foetens	1				16	3	18	14	21	34	23	8
Larimus fasciatus		2	3	3	9	13	3		4	18	20	2
Total number of individuals	6082	11445	29698	43146	48432	28542	15235	29569	9007	14774	8688	6907
Total number of species	46	41	45	41	42	44	45	48	49	44	46	50
Total number of trawl tows	110	115	126	128	130	129	129	130	130	130	128	129

Temporal distribution:	1964											
Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Micropogonias undulatus	740	4469	10181	13887	15919	8046	4140	1223	472	235	1121	1421
Anchoa mitchilli	1745	1184	1336	814	2393	544	669	296	391	5564	4030	1144
Stellifer lanceolatus	30	39	13	52	47	759	1237	881	758	342	241	93
Leiostomus xanthurus	46	81	175	765	2642	1457	1031	644	403	210	155	111
Cynoscion arenarius	5	13	8	20	1479	1045	1102	614	278	288	181	111
Arius felis			78	9	14	33	122	512	473	472	792	25
Sphoeroides parvus	2	38	63	22	36	297	451	199	276	227	298	316
Brevoortia patronus	153	579	156	190	127	237	55	26	119	22	40	133
Symphurus plagiusa	354	197	89	118	65	78	114	64	66	102	246	356
Citharichthys spilopterus			7	6	233	326	162	56	29	8	6	1
Polydactylus octonemus	2		1	48	654	33	77	4				
Menticirrhus americanus	20	38	20	15	14	28	32	15	23	104	59	98
Mugil cephalus	282	300	5	7	4	6	9	8	2	7	2	39
Bagre marinus							35	319	88	17		
Achirus lineatus	1						1	10	40	24	18	22
Prionotus tribulus	23	14	34	27	36	8	11	4	3	15	21	19
Etropus crossotus	6	2	1	1	1	11	25	33	18	46	63	53
Porichthys plectrodon			1	4	5	8	15	13	8	21	13	1
Paralichthys lethostigma	6	8	5	45	2	7	8	1	3	1	4	11
Urophycis floridanus	1	72	91	51			1					
Bairdiella chrysoura	2	3	1			3	5	94	20	1	3	14
Chaetodipterus faber				1	4	1	18	27	18	9	7	5
Cyprinodon variegatus	81	7										6
Synodus foetens			1		5	1	4	6	4	5	8	2
Larimus fasciatus	18	11	1	5	7	2	13	1		2	5	
Total number of individuals	3646	7172	12299	16115	23758	12960	9452	5081	3566	7830	7348	4063
Total number of species	39	37	36	33	37	36	46	36	36	39	34	47
Total number of trawl tows	128	128	65	65	65	65	65	65	65	65	65	64

TABLE 2 (Continued)

Areal distribution: Species	2-yr Total	Zone C	Zone O	Zone S	Zone P	Subarea GM	Subarea TP	Subarea LG	Subarea UG	Subarea MS	Subarea TB	Subarea EB
Micropogonias undulatus	186822	11348	77858	57768	39848	1140	2442	22569	22207	18462	50767	69235
Anchoa mitchilli	81175	2436	44926	21959	11854	544	3295	18272	14540	5080	24479	14965
Stellifer lanceolatus	29267	24548	4041	456	222	1359	614	15506	8991	1619	248	930
Leiostomus xanthurus	14979	224	1561	7816	5378	91	312	1411	1226	1338	3167	7434
Cynoscion arenarius	11927	1617	6375	1731	2204	1345	804	2665	1500	688	1835	3090
Arius felis	8928	987	2550	4809	582	26	265	1703	2764	1565	1623	982
Sphoeroides parvus	6303	224	2550	3095	434	72	398	438	902	2100	1603	790
Brevoortia patronus	4729	315	763	2708	943	5	36	186	739	541	1011	2211
Symphurus plagiusa	4316	2592	992	199	533	458	316	957	1230	662	175	518
Citharichthys spilopterus	3755	255	1799	649	1052	84	185	919	549	61	626	1331
Polydactylus octonemus	2221	1019	879	260	63	168	1312	319	153	103	29	137
Menticirrhus americanus	1624	579	517	512	16	182	540	484	120	16	41	241
Mugil cephalus	1589	1	167	342	1079		23	91	196	57	289	933
Bagre marinus	1021	133	394	339	155		7	73	259	150	335	197
Achirus lineatus	701	43	234	52	372	2	10	108	96	39	157	289
Prionotus tribulus	697	131	293	205	68	98	75	116	122	72	95	119
Etropus crossotus	647	153	346	131	17	56	57	291	79	19	31	114
Porichthys plectrodon	385	109	188	38	50	65	16	106	66	14	72	46
Paralichthys lethostigma	345	11	32	48	254		11	69	67		48	150
Urophycis floridanus	274	183	53	9	29	21	22	46	99	44	1	41
Bairdiella chrysoura	259	100	75	60	24	4	16	114	32	14	27	52
Chaetodipterus faber	195	49	48	63	35	5	12	65	16	27	24	46
Cyprinodon variegatus	191	1	12	24	154			9	2	6	2	172
Synodus foetens	174	13	69	52	40	5	35	46	25		12	51
Larimus fasciatus	142	50	91	1		54	79	3			1	5
Total number of individuals	364815	47533	147435	103853	65994	5913	11159	67069	56230	32796	87071	104577
Total number of species	96	65	80	74	73	47	50	76	57	47	61	70
Total number of trawl tows	2419	340	1002	740	337	75	183	526	372	186	517	560

late summer occasions. Parker (1971) gives a thorough treatment of the abundance and distribution of *Micropogonias undulatus* and *Leiostomus xanthurus*. *Cynoscion arenarius* and *Leiostomus xanthurus* were generally most abundant in spring and summer while *Arius felis* peaked in summer and fall. Other numerous species which showed seasonal abundance peaks included: *Symphurus plagiusa* and *Mugil cephalus* in winter; *Brevoortia patronus, Citharichthys spilopterus,* and *Polydactylus octonemus* in spring; *Sphoeroides parvus, Bagre marinus,* and *Achirus lineatus* in summer; and *Etropus crossotus* and *Porichthys plectrodon* in fall.

Fishes were generally most abundant in April and May and least abundant in December and January (Table 2). More species were collected in December of each year than in other months, although the monthly variation (taking into account the number of tows per month) was not great—41 to 50 species in 1963, 33 to 47 species in 1964.

Collections were grouped according to zones and subareas (Table 2). The peripheral zone yielded the greatest number of individuals per tow (N/T) over the study period: N/T = 195.8, 147.1, 140.3, and 139.8 for peripheral, open water, shore, and channel zones, respectively. Species per tow (S/T) were higher in peripheral (0.22) and channel (0.19) zones than inshore (0.10) and open water (0.08) zones. With respect to subareas, fishes were more abundant in the East Bay, San Jacinto River, Trinity Bay, and Upper Galveston Bay subareas (N/T = 186.7, 176.3, 168.4, and 151.2, respectively) and distinctly less abundant in Lower Galveston Bay, the Gulf of Mexico, and the Tidal Pass (N/T = 127.5, 78.8, and 61.0, respectively). Species were by far more numerous in the Gulf subarea (S/T = 0.63) than elsewhere (S/T = 0.12 to 0.27). *Stellifer lanceolatus* was the most abundant species in the

TABLE 3

Total abundances of species which occurred in Galveston Bay in 1963–1964 and which are not listed in Table 2.

Species	No.	Species	No.
Gobiosoma bosci	126	*Syngnathus scovelli*	13
Trinectes maculatus	126	*Ictalurus punctatus*	13
Lagodon rhomboides	120	*Gobionellus boleosoma*	12
Gobiesox strumosus	107	*Membras martinica*	12
Menidia beryllina	107	*Microgobius gulosus*	12
Myrophis punctatus	88	*Hypsoblennius ionthas*	11
Dorosoma cepedianum	88	*Chilomycterus schoepfi*	8
Pogonias cromis	81	*Elops saurus*	7
Mugil curema	77	*Harengula jaguana*	6
Chloroscombrus chrysurus	72	*Hemicaranx amblyrhynchus*	6
Orthopristis chrysoptera	71	*Peprilus paru*	5
Dorosoma petenense	68	*Caranx bartholomaei*	4
Oligoplites saurus	62	*Chaenobryttus gulosus*	4
Peprilus burti	57	*Ictiobus bubalus*	4
Cynoscion nebulosus	56	*Chasmodes bosquianus*	3
Eucinostomus gula	53	*Dormitator maculatus*	3
Ancylopsetta quadrocellata	50	*Lepisosteus spatula*	3
Gobionellus hastatus	49	*Monacanthus hispidus*	3
Sciaenops ocellatus	45	*Opisthonema oglinum*	3
Fundulus similis	44	*Selene setapinnis*	3
Dasyatis sabina	40	*Gymnothorax moringua*	2
Archosargus probatocephalus	39	*Lepisosteus osseus*	2
Centropristis philadelphica	37	*Lutjanus synagris*	2
Ophichthus gomesi	37	*Poecilia latipinna*	2
Syngnathus floridanus	37	*Selene vomer*	2
Astroscopus y-graecum	36	*Cyprinus carpio*	1
Ictalurus furcatus	32	*Dasyatis sayi*	1
Fundulus grandis	28	*Gobionellus shufeldti*	1
Anchoa hepsetus	27	*Hippocampus zosterae*	1
Caranx hippos	26	*Lepomis macrochirus*	1
Microgobius thalassinus	21	*Ogcocephalus radiatus*	1
Lepisosteus oculatus	20	*Raja texana*	1
Opsanus beta	19	*Scorpaena calcarata*	1
Cynoscion nothus	19	*Seriola rivoliana*	1
Trichiurus lepturus	15	*Trachinotus carolinus*	1
Prionotus scitulus	14		

channel zone and co-dominated with *Cynoscion arenarius* in the Gulf subarea. *Micropogonias undulatus* predominated in all other zones and subareas except in the Tidal Pass, where *Anchoa mitchilli* was the most numerous species.

SEASONALITY

The fish communities in the various zones and subareas demonstrated several seasonal trends in both mean total numbers per tow and mean total biomass per tow (B/T). In the peripheral zone, fishes were most numerous in March, yet biomass peaks were found in April–May and August (Figure 2).

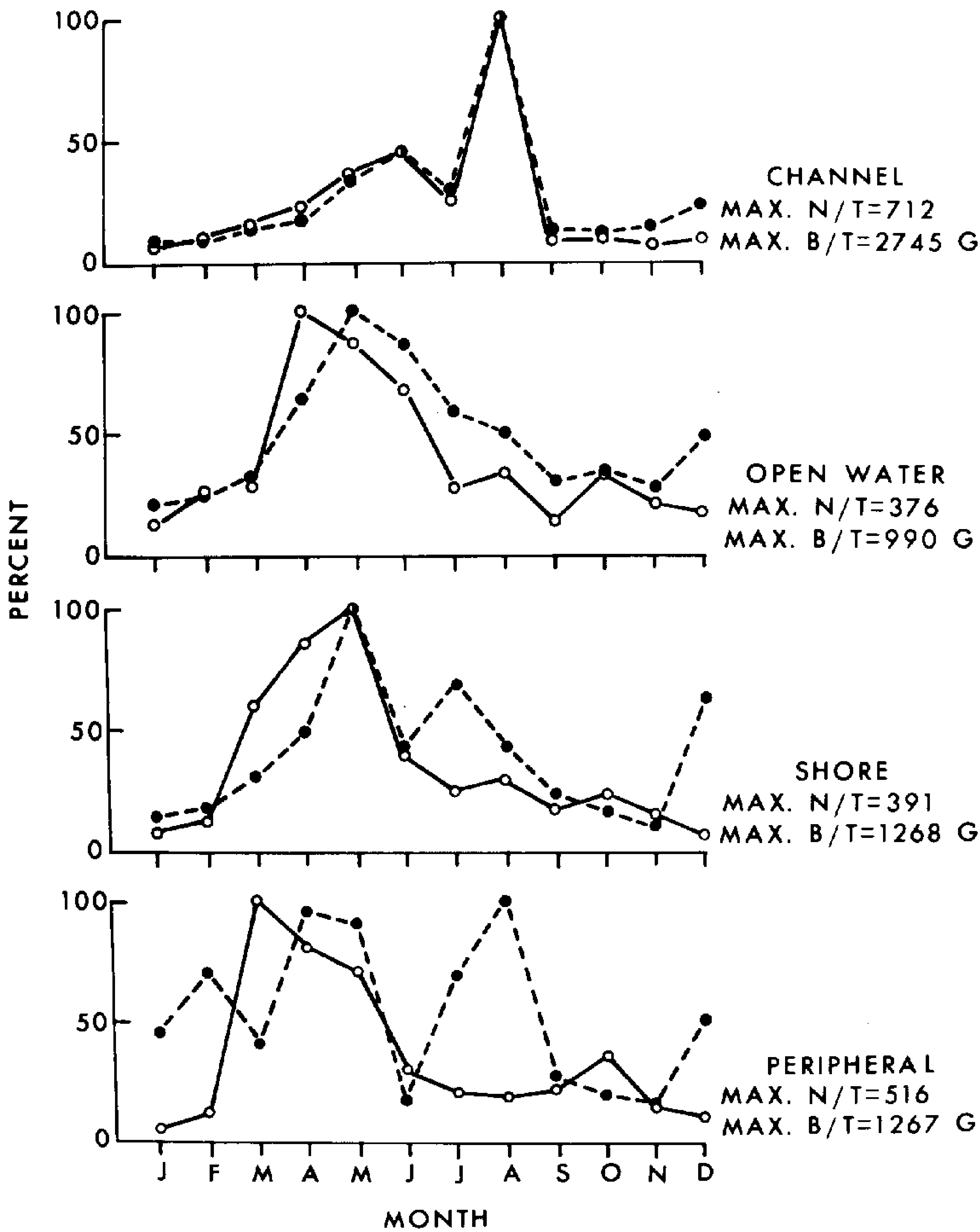

FIG. 2. Percentage of maximum mean monthly number per tow (N/T, —o—) and biomass per tow (B/T, --●--) for all fishes by Galveston Bay depth zone.

In the shore zone, both numbers and biomass peaked in May, while in the open water zone, numbers peaked in April and biomass peaked in May. Both numbers and biomass of fishes in the channel zone were at a maximum in August. The seasonal variations of N/T and B/T within each zone were significantly ($P<0.05$) correlated in the channel, open water, and shore zones, but not in the peripheral zone. Inter-zone comparison of N/T and B/T (Table 4) showed significant (P<0.05) correlations in N/T trends among all

TABLE 4

Matrices of correlation coefficients comparing mean monthly number and biomass of fishes per tow (N/T and B/T, respectively) in zones and subareas of Galveston Bay, 1963–1964. Significant correlations (P < .05) are indicated by asterisks (*). Other information is given in Table 1.

		Zones				
		C	O	S	P	
	C		.441	.374	.359	
	O	.334		.854*	.374	B/T
N/T	S	.283	.877*		.336	
	P	.096	.526*	.776*		

		Subareas							
		GM	TP	LG	UG	MS	TB	EB	
	GM		.837*	.012	.271	.331	.668*	.503*	
	TP	.745*		.069	.282	.474	.722*	.584*	
	LG	.174	.207		.608*	.340	.297	.267	B/T
N/T	UG	.365	.436	.721*		.338	.605*	.419	
	MS	.254	.466	.366	.618*		.573*	.729*	
	TB	.634*	.807*	.276	.717*	.662*		.438	
	EB	.272	.462	.291	.713*	.873*	.821*		

but the channel zone, while B/T trends were only correlated in the open water and shore zones. Within each subarea, seasonal variations in N/T and B/T were significantly (P<0.05) correlated in all but East Bay (Figures 3–4). Maximum numbers of fishes were collected during April in East Bay and the mouth of the San Jacinto River, during May in Trinity Bay and the Tidal Pass, during June in the Gulf waters, and during August in Lower Galveston Bay. A bimodal trend was found in Upper Galveston Bay, where abundance peaks were found in April and August. Comparisons of N/T and B/T between subareas (Table 4) demonstrated that adjoining subareas generally had similar trends in numbers of fishes (excepting Lower Galveston Bay), and that biomass trends were not as well linked. The N/T and B/T trends in the Trinity Bay subarea were correlated with most other subareas, while those in the Lower Galveston Bay subarea were correlated only with Upper Galveston Bay.

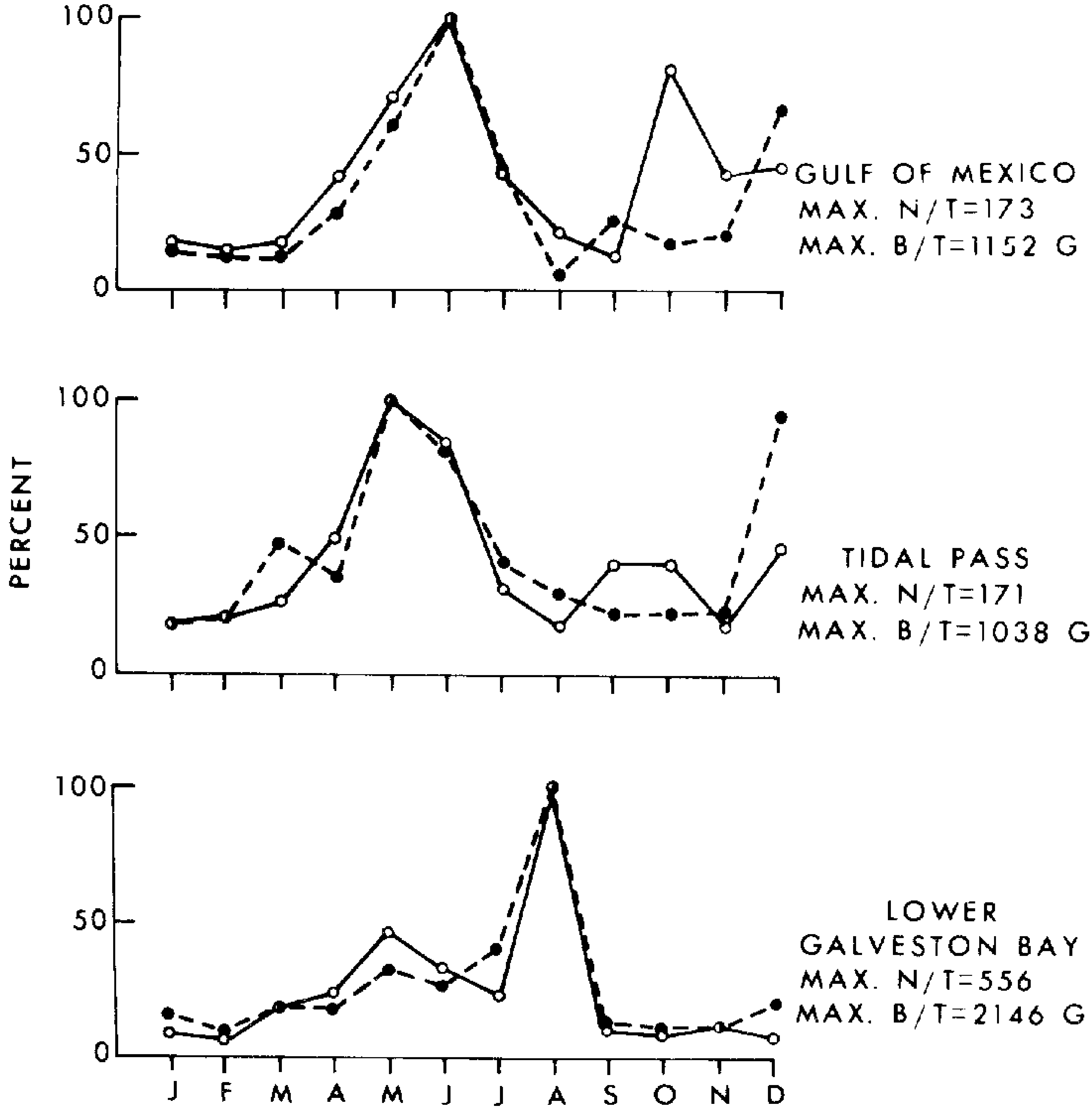

FIG. 3. Percentage of maximum mean monthly number per tow (N/T, —o—) and biomass per tow (B/T, --•--) for all fishes by Galveston Bay subarea.

NUMERICAL ABUNDANCE

The overall distributions of the six most numerous fishes and of the total fish fauna by zone and subarea are summarized in Table 5. *Micropogonias undulatus* was generally most numerous in the peripheral zone of each subarea and in the lower salinity subareas of each zone. Its peak abundance was in the peripheral zone of East Bay (N/T = 235.2), where the total fish fauna was also highest (N/T = 397.8). *Anchoa mitchilli* tended to be more numerous in the open water zones of mid-estuary and in the peripheral zones of the lower salinity subareas. *Anchoa mitchilli* was most abundant in the open waters of Upper Galveston Bay (N/T = 77.2) and in the peripheral waters of Trinity Bay (N/T = 71.2). *Stellifer lanceolatus* occurred primarily in the channel zones of Upper and Lower Galveston Bay (N/T = 115.8 and 116.4). *Leiostomus xanthurus* was most abundant in the peripheral zone of

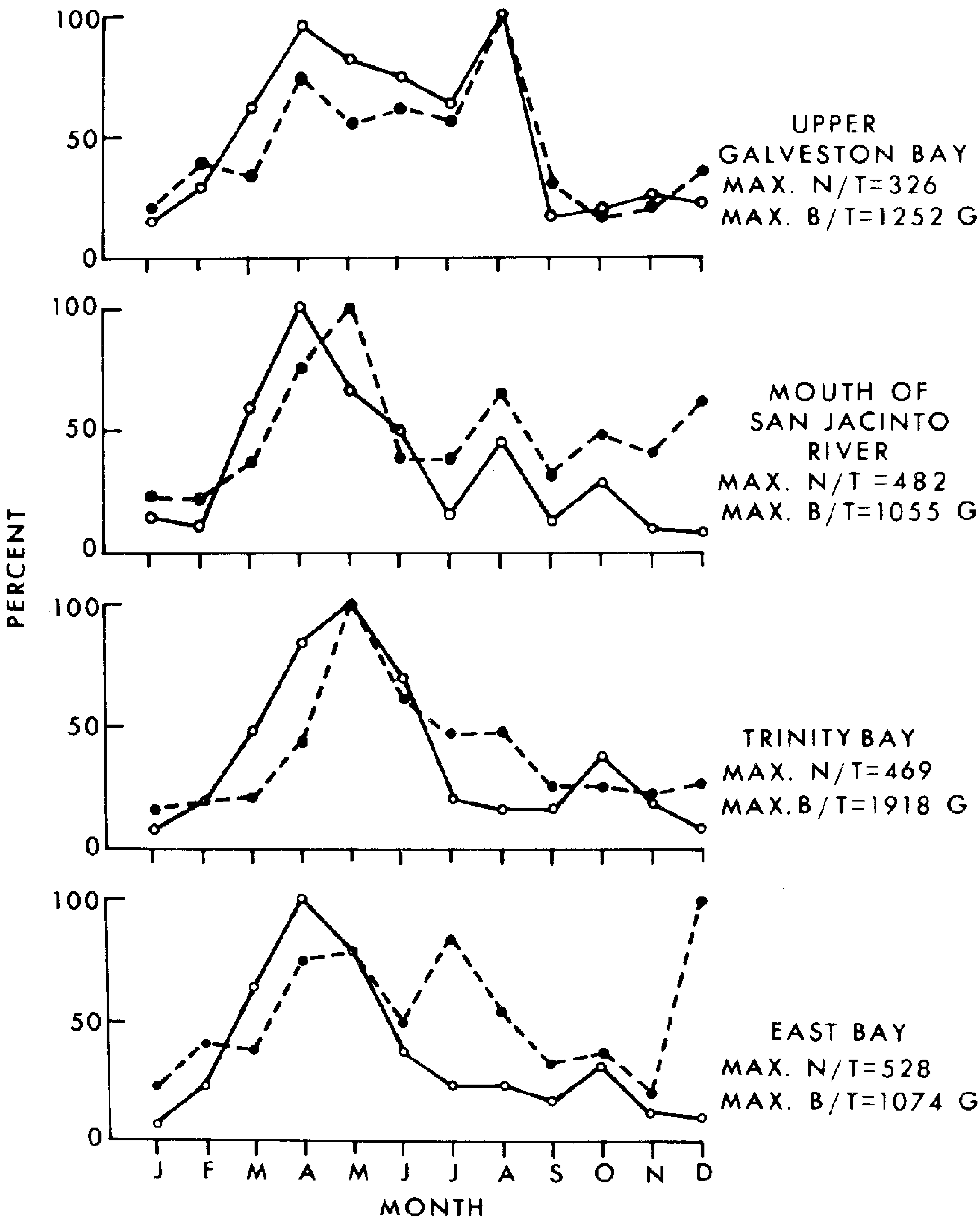

FIG. 4. Percentage of maximum mean monthly number per tow (N/T, —o—) and biomass per tow (B/T, --•--) for all fishes by Galveston Bay subarea.

East Bay (N/T = 54.5). *Cynoscion arenarius* was collected primarily in the channel and open water zones of the Gulf of Mexico (N/T = 13.7 and 22.3) and in the peripheral zone of East Bay (N/T = 18.1). *Arius felis* occurred most frequently in the shore zones of Upper Galveston Bay and the mouth of the San Jacinto River (N/T = 21.0 and 13.8).

The abundance patterns of *M. undulatus, L. xanthurus,* and *C. arenarius* were highly correlated between the two years of sampling (Table 6). These

TABLE 5

Mean number of fishes per tow (N/T) in zone-subarea combinations for the six most abundant fishes and the total fish fauna in Galveston Bay, 1963–1964.Asterisk (*) indicates the dominant fish in each combination. Other information is given in Table 1.

	Zone					Zone			
Subarea	C	O	S	P	Subarea	C	O	S	P
		M. undulatus					*A. mitchilli*		
GM	17.8	12.6	-	-	GM	9.3	5.1	-	-
TP	16.8*	12.6	-	6.8	TP	15.8	13.1*	-	35.4*
LG	22.8	38.9	36.7	95.8*	LG	2.3	59.9*	38.4*	13.8
UG	59.9	62.2	38.1*	74.6*	UG	6.3	77.2*	28.2	15.4
MS	62.5*	136.6*	81.5*	-	MS	4.0	37.3	29.4	-
TB	-	109.8*	78.0*	122.5*	TB	-	53.6	32.9	71.2
EB	-	97.5*	118.0*	235.2*	EB	-	26.7	21.2	44.1
		S. lanceolatus					*L. xanthurus*		
GM	22.0*	14.1	-	-	GM	1.1	1.4	-	-
TP	5.0	3.0	-	<0.1	TP	0.4	1.9	-	4.3
LG	116.4*	11.7	0.2	0.1	LG	0.2	0.6	3.5	9.9
UG	115.8*	2.6	0.9	<0.1	UG	1.2	1.0	7.2	5.4
MS	39.2	0.9	0.9	-	MS	1.1	3.9	13.5	-
TB	-	1.0	0.1	0.0	TB	-	0.7	13.5	1.0
EB	-	1.7	1.2	1.9	EB	-	2.5	12.5	54.4
		C. arenarius					*A. felis*		
GM	13.7	22.3*	-	-	GM	0.5	0.2	-	-
TP	4.3	4.4	-	4.5	TP	0.5	2.2	-	2.0
LG	2.8	9.6	1.7	3.8	LG	4.9	0.9	5.2	2.7
UG	4.5	5.6	1.9	2.9	UG	3.9	5.2	21.0	2.1
MS	3.0	3.9	3.9	-	MS	2.3	6.0	13.8	-
TB	-	5.2	2.1	2.8	TB	-	3.4	3.9	0.2
EB	-	4.4	2.7	18.1	EB	-	1.1	2.6	0.5
		All Fishes							
GM	87.0	70.5	-	-					
TP	63.9	59.2	-	58.1					
LG	161.6	130.9	93.8	134.1					
UG	211.4	162.7	109.6	116.7					
MS	139.8	206.1	165.8	-					
TB	-	182.9	140.2	207.9					
EB	-	140.3	173.3	397.8					

three dominants plus *A. felis* demonstrated similar mean N/T values when summed over all stations and months in each year, even though there were instances of significant differences in N/T values between similar months in successive years. This was not the case for *A. mitchilli* and *S. lanceolatus,* both of which showed distinctive abundance patterns in successive years and higher overall N/T values in 1963. In all but 2 months, the 1963 system-wide N/T values for *A. mitchilli* exceeded those in 1964, significantly so in six of those months. The differences in *S. lanceolatus* abundance were mainly attributable to a single month (August 1963) when an extremely large catch was recorded. Although the N/T values for the total fish fauna showed a high degree of regularity between years, the catch was significantly higher in

TABLE 6

Comparison of monthly and yearly mean number of fishes per tow (N/T) collected over all stations for the six most numerous fishes and the total fish fauna in Galveston Bay, 1963–1964. Asterisk (*) indicates both significant differences (χ^2, $P < .05$) between corresponding months in each year and significant correlations (r, $P < .05$) in trends between years.

	YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN-DEC	r
Micropogonias undulatus	1963	28.4*	41.2	185.0	286.0*	279.3	95.8	36.3	13.3	2.9	1.6	4.5	7.2	82.5	.977*
	1964	5.8	34.9	156.6	213.6	244.9	123.8*	63.7*	18.8	7.3	3.6	17.2*	22.2*	68.3	
Anchoa mitchilli	1963	16.8	47.8*	28.2	33.8*	47.0	77.2*	22.4*	26.0*	32.0*	78.6	45.4	25.6	40.3*	.546
	1964	13.6	9.3	20.6	12.5	36.8	8.4	10.3	4.6	6.0	85.6	62.0	17.9	22.2	
Stellifer lanceolatus	1963	0.1	0.1	0.1	0.4	1.0	12.8	24.8	130.0*	7.8	7.0	5.3	1.6	16.4*	.465
	1964	0.2	0.3	0.2	0.8	0.7	11.7	19.0	13.6	11.7	5.3	3.7	1.5	5.0	
Leiostomus xanthurus	1963	1.4	1.0	1.2	7.2	15.1	7.5	10.1	5.8	2.3	1.2	0.6	3.1	4.8	.942*
	1964	0.4	0.6	2.7	11.8	40.6*	22.4*	15.9	9.9	6.2	3.2	2.4	1.7	8.5	
Cynoscion arenarius	1963	0.2	0.1	0.4	2.7	9.0	6.7	7.4	8.7	3.6	9.5	3.1	1.2	4.5	.764*
	1964	0.1	0.1	0.1	0.3	22.8*	16.1*	12.0	9.4	4.3	4.4	2.8	1.7	5.7	
Arius felis	1963	0.1	0.1	0.2	0.3	0.3	0.3	2.2	26.4*	11.2	7.8	0.4	0.1	4.2	.535
	1964	0.0	0.0	1.2	0.1	0.2	0.5	1.9	7.9	7.3	7.3	12.2*	0.4	2.8	
Total Fishes	1963	55.3*	99.5*	235.7*	337.1*	372.6	221.3	118.1	227.5*	69.3	113.6	67.9	53.5	166.1*	.881*
	1964	28.5	56.0	189.2	247.9	365.5	199.4	145.4	78.2	54.9	120.5	113.0*	63.5	125.2	

1963 and was particularly so in the January-April collections. If either the high 1963 *A. mitchilli* or *S. lanceolatus* catches were regarded as abnormal and were adjusted downward to 1964 catch rates, then the overall N/T for the total fish faunas in 1963 and 1964 would not be significantly different.

Comparison of annual N/T values between years for the total fish faunas found in the various zone-subarea combinations (Table 7) demonstrated the fluctuating abundances in local fish faunas and the effects of the dominant species on local catch rates. In most cases, catches were higher in 1963 than in 1964. *Stellifer lanceolatus, A. mitchilli,* and *M. undulatus* populations were most responsible for local catch differences, although in some instances (*e.g.,* channel zone of the Gulf of Mexico) changes in fish catch were due to an overall increase (or decrease) in all fishes collected.

The areas of maximum abundance of 59 fishes over the 24-month period are presented in Table 8, along with the dominant fish in each zone-subarea combination. Thirty-seven species were not abundant enough to determine such information. Most species had maximum N/T values of less than 5, aside from the previously discussed dominants. The exceptions included: *Polydactylus octonemus,* N/T = 10.3 in the channel zone of the Tidal Pass; *Symphurus plagiusa,* N/T = 14.5 in the channel zone near the San Jacinto River; *Sphoeroides parvus,* N/T = 16.2 in the shore zone of the San Jacinto River; *Brevoortia patronus,* N/T = 8.0 in the shore zone of East Bay; and *Mugil cephalus,* N/T = 10.0 and *Citharichthys spilopterus,* N/T = 8.2 in the peripheral zone of East Bay.

BIOMASS

Seven fishes, including the six numerical dominants, comprised 73.8% of the total biomass (Table 9). *Micropogonias undulatus* was by far the

TABLE 7

Comparison of 1963 and 1964 annual mean number of fishes per tow (N/T) by zone and subarea in Galveston Bay, Texas. Species whose annual fluctuations in abundance most affected the N/T values are indicated by superscripts as follows: 1= *Stellifer,* 2=*Anchoa mitchilli,* 3=*Micropogonias,* 4=*Arius,* 5=*Brevoortia,* 6=*Leiostomus.* Other information as in Table 1.

		ZONE			
Subarea	Yr	C	O	S	P
GM	63	73.2	66.8	-	-
	64	110.5	76.6	-	-
TP	63	66.8	56.7	-	100.8[2]
	64	59.0	63.4	-	6.2
LG	63	222.9[1]	149.5[2]	107.7[23]	130.2
	64	56.6	99.5	70.8	140.9
UG	63	254.8[1]	167.9	136.5[234]	90.6[3]
	64	140.1	150.9	64.5	148.5
MS	63	148.9[1]	274.3[3]	189.4[23]	-
	64	124.2	96.5	126.1	-
TB	63	-	204.8[2]	121.5[2356]	227.0[2]
	64	-	145.9	170.1	177.3
EB	63	-	168.9[3]	187.5[35]	390.9
	64	-	91.9	149.7	408.9

dominant fish with 36.5% of the 24-month total biomass. Other dominants included *L. xanthurus* (9.1% of the total biomass), *M. cephalus* (7.6%), *S. lanceolatus* (6.5%), *A. felis* (5.7%), *C. arenarius* (5.0%), *A. mitchilli* (3.7%), *S. plagiusa* (2.7%), *Pogonias cromis* (2.3%), *Lepisosteus oculatus* (2.0%), and *Dasyatis sabina* (2.0%). *Micropogonias undulatus* was the biomass dominant in 14 of 24 months (spring and summer), *M. cephalus* predominated in 5 winter months, *A. felis* in 4 fall months, and *S. lanceolatus* once in late summer. The monthly biomass patterns of *M. undulatus, M. cephalus, C. arenarius,* and *A. mitchilli* were significantly correlated between the two years of sampling (Table 10). *Anchoa mitchilli* was the only one of these four species that had a significantly higher annual biomass per tow (B/T) value in one of the two years. The monthly B/T values of *A. mitchilli* were higher in 11 of 12 months in 1963, significantly so in six of those months. Biomass catches were higher in the 1964 summer months for both *M. undulatus* and *C. arenarius* but did not affect the annual catch values. Monthly B/T differences occurred erratically in the *M. cephalus* population. Monthly biomass patterns were not correlated between years for *L. xanthurus, S. lanceolatus,* and *A. felis.* Catches of *L. xanthurus* were much higher in the

TABLE 8

Zone-subarea combinations of maximum mean number per tow (N/T) of 59 fishes collected in Galveston Bay, 1963–1964. Thirty-seven species are not included due to N/T values less than 0.1. Dashes indicate combinations wherein no species reached a maximum. Other information in Table 1.

Subarea	Channel	Open Water
GM	*Etropus crossotus* 1.2 *Centropristis philadelphica* 0.5	*Cynoscion arenarius* 22.3 *Prionotus tribulus* 1.4 *Porichthys plectrodon* 1.1 *Larimus fasciatus* 0.9 *Anchoa hepsetus* 0.6 *Cynoscion nothus* 0.5 *Prionotus scitulus* 0.1
TP	*Polydactylus octonemus* 10.3 *Peprilus burti* 0.4 *Astroscopus y-graecum* 0.2 *Lagodon rhomboides* 0.2	*Menticirrhus americanus* 4.4 *Orthopristis chrysoptera* 0.8 *Dasyatis sabina* 0.1
LG	*Stellifer lanceolatus* 116.4 *Bairdiella chrysoura* 0.8 *Gobionellus hastatus* 0.1	
UG	*Urophycis floridanus* 1.2 *Ancylopsetta quadrocellata* 0.1 *Opsanus beta* 0.1	*Anchoa mitchilli* 77.2
MS	*Symphurus plagiuse* 14.5 *Gobiesox strumosus* 0.6 *Chaetodipterus faber* 0.3 *Dorosoma petenense* 0.2 *Ophichthus gomesi* 0.2	-
TB	-	-
EB	-	-

Subarea	Shore	Peripheral
GM	-	-
TP	-	*Synodus foetens* 0.8 *Eucinostomus gula* 0.6 *Gobionellus boleosoma* 0.3
LG	*Oligoplites saurus* 0.4 *Chloroscombrus chrysurus* 0.1	*Achirus lineatus* 1.2 *Fundulus grandis* 0.1
UG	*Arius felis* 21.0 *Bagre marinus* 1.9 *Myrophis punctatus* 0.3	*Paralichthys lethostigma* 0.6 *Cynoscion nebulosus* 0.2 *Gobiosoma bosci* 0.1

TABLE 8 (Continued)

MS	*Sphoeroides parvus* 16.2 *Elops saurus* 0.1	-
TB	*Pogonias cromis* 0.1	*Lepisosteus oculatus* 0.3 *Trinectes maculatus* 0.3 *Dorosoma cepedianum* 0.2 *Ictalurus furcatus* 0.2 *Ictalurus punctatus* 0.1
EB	*Brevoortia patronus* 8.0	*Micropogonias undulatus* 235.2 *Leiostomus xanthurus* 54.4 *Mugil cephalus* 10.0 *Citharichthys spilopterus* 8.2 *Cyprinodon variegatus* 2.0 *Mugil curema* 1.0 *Menidia beryllina* 0.5 *Fundulus similis* 0.4 *Sciaenops ocellatus* 0.3

last seven months of 1964, which lead to a significantly higher biomass catch rate for that year, even though N/T values were similar. The difference in *S. lanceolatus* B/T values was again related to extremely high catches in August 1963. Although the annual B/T values for *A. felis* were similar, the variations between similar months in successive years led to a lack of correlation between 1963 and 1964. It was interesting to find, despite monthly variations, that the biomass catch rates for the total fish fauna were similar between years and that the monthly patterns were also correlated.

OTHER GALVESTON BAY STUDIES

Bechtel and Copeland (1970) conducted one year of quarterly fish sampling on 28 stations in the estuary, which included 8 stations in West Bay, an area not covered by the 1963–1964 survey. They used a 3-m trawl with 20-mm mesh wing and body and 6-mm mesh cod end towed for 10 minutes (day or night was not specified). In contrast, the 1963–1964 survey used a 3-m net with coarser mesh (35-mm body, 25-mm cod end) for 5-min daylight tows. Bechtel and Copeland were primarily interested in species diversity, and they concluded that pollution was responsible for reduced diversity in certain areas of the estuary. Few numerical data were presented, but several comparisons can be made: 1) *M. undulatus* and *A. mitchilli* were the most abundant species in both studies, 2) *L. xanthurus* and *S. lanceolatus* were more abundant in 1963–1964 than in 1969, while the reverse was true for *A. felis* and *C. arenarius,* and 3) numbers and biomass per tow were approximately three times higher in 1969 than in 1963–1964, probably due to the finer mesh net used in 1969.

There have been no other comprehensive studies of the fish fauna of the Galveston Bay estuarine system. Several investigations of environmental alterations have been made on limited portions of the estuary (Table 11);

TABLE 9

Monthly biomasses (grams, wet weight) of the 20 biomass dominants and of all species collected in Galveston Bay in 1963 and 1964.

Species	1963 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Micropogonias undulatus	4875	7352	18648	53082	90409	52283	34950	19473	5943	3661	6773	5791	303240
Leiostomus xanthurus	3561	3004	4527	9958	6402	10276	8016	3810	2766	2766	1646	6781	63513
Mugil cephalus	8946	16947	3967	1659	1167	43	506	855	191	91	557	29904	64833
Stellifer lanceolatus	24	3	21	641	408	2236	5507	55773	3211	2705	1789	1108	73426
Arius felis	67	5	1625	2852	5444	4206	5016	11648	11263	8341	561	30	51058
Cynoscion arenarius	174	36	215	812	2551	5043	7808	6526	2946	2954	2936	2048	34049
Anchoa mitchilli	851	1759	1740	3442	5376	6374	1934	1928	2119	6234	5001	2481	39239
Symphurus plagiusa	832	1844	1460	874	848	1503	876	1455	1730	2493	3549	3987	21451
Pogonias cromis	2111	927	1030	631			1369	206	34	172	215	5379	12074
Lepisosteus oculatus				369			4499	9800					14668
Dasyatis sabina			5975	2721	2589	4891	1099	2761	233	485		475	21229
Menticirrhus americanus	747	1306	3029	766	714	842	245	245	1170	222	510	4861	14657
Sphoeroides parvus	273	6	479	342	441	1011	1785	2084	1838	782	1312	1802	12155
Brevoortia patronus	906	1764	2201	264	53	256	291	839	199	134	585	2897	9989
Archosargus probatocephalus	194	2933		1		1174	2564	2055		2463	1068		12452
Polydactylus octonemus			5	350	2661	3903	1842	747	294				9802
Paralichthys lethostigma	1899	2333	1183	893	1270	331	941	1287	879	106	557	361	12040
Bagre marinus					812	239	1763	3753	930	438			7935
Lepisosteus spatula												3178	3178
Citharichthys spilopterus	85	164	20	73	1239	1812	1755	1578	720	481	220	114	8261
Total Biomass, all fishes	29525	47041	49878	75822	127524	94297	96243	134968	40850	38197	31080	77093	842518
Total number of trawl tows	110	115	126	128	130	129	129	130	130	130	128	129	1514

Species	1964 Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	2-YR Total
Micropogonias undulatus	2168	4469	10995	26663	43777	39747	34983	14174	6004	2750	4988	6238	196956	500196
Leiostomus xanthurus	1311	2415	2319	1476	10251	9223	9990	8585	5038	3039	3663	3405	61437	124950
Mugil cephalus	14213	12255	698	1733	1185	929	222	809	206	1240	303	5789	39582	104415
Stellifer lanceolatus	64	100	52	329	415	1093	5282	1903	2448	1139	2747	530	16102	89528
Arius felis			2661	732	585	1720	4119	3830	3339	3700	5702	158	26546	77604
Cynoscion arenarius	15	69	43	151	2189	5570	11362	6625	2916	1716	1792	1375	33823	67872
Anchoa mitchilli	593	616	775	806	2249	517	522	189	313	2114	2660	618	11972	51211
Symphurus plagiusa	2818	1346	700	997	250	413	832	595	635	1077	1887	4030	15580	37031
Pogonias cromis	2177	2974			8443		457	233	134	242		4805	19465	31539
Lepisosteus oculatus		1362		5454	1304	786	4179						13805	27753
Dasyatis sabina			1942		669	1445		77	720		720	445	6018	27247
Menticirrhus americanus	312	1469	694	562	100	118	465	149	148	440	408	3132	7997	22654
Sphoeroides parvus	6	257	457	248	249	377	884	436	980	1078	1648	3384	10004	22159
Brevoortia patronus	676	1575	460	407	201	1128	195	701	770	200	670	1206	8589	18578
Archosargus probatocephalus	2526		322					791	1348	354			5341	17793
Polydactylus octonemus	43		5	268	3473	878	2436	237					7340	17142
Paralichthys lethostigma	993	496	11	55	339	611	483	83	71	53	436	737	4368	16408
Bagre marinus							213	3097	2259	261			5830	13756
Lepisosteus spatula					6804		1863						8667	11845
Citharichthys spilopterus			15	37	172	632	732	438	340	79	106	2	2553	10814
Total Biomass, all fishes	31338	31985	23745	42295	84043	68244	81887	44568	30327	21142	29424	38624	527622	1370140
Total number of trawl tows	128	128	65	65	65	65	65	65	65	65	65	64	905	2419

however, such studies are not truly inter-comparable with the 1963–1964 investigation due to variations in gear, numbers of stations, etc. Reid (1957) summarized trawl surveys of the East Bay subarea 6 months before and 6 and 18 months after the January 1955 opening of Rollover Pass (approximately 16 km northeast of Galveston, Figure 1). Reid associated year-to-year fluctuations in abundance and composition of the fish fauna with extreme changes in the salinity structure of East Bay due to the new pass. Reid found that *M. undulatus* and *A. mitchilli* were the subarea co-dominants (33.7 and 31.0% of the total fishes) in three successive Junes (1954–1956). In June of

Table 10

Comparison of monthly and yearly mean biomass (grams) of fishes per tow (B/T) collected over all stations for the seven biomass dominants and the total fish fauna in Galveston Bay, 1963–1964. Asterisk (*) indicates both significant differences (χ^2, $P < .05$) between corresponding months in each year and significant correlations (r, $P < .05$) in trends between years.

	YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN-DEC	r
Micropogonias undulatus	1963	44.3*	63.9*	148.0	414.7	695.5	405.3	270.9	149.8	45.7	28.2	52.9	45.2	200.3	.925*
	1964	16.9	34.9	169.2	410.2	673.5	611.5*	538.2*	218.1*	92.4*	42.3	76.7*	97.5*	217.6	
Leiostomus xanthurus	1963	32.4*	26.1	35.9	77.8*	49.2	79.7	62.1	29.3	21.3	21.3	12.9	53.0	42.0	.342
	1964	10.2	18.9	35.7	22.7	157.7*	141.9*	153.7*	132.1*	77.5*	46.8*	56.4*	53.2	67.9*	
Mugil cephalus	1963	81.3	147.4*	31.5*	13.0	9.0	0.3	3.9	6.6	1.5	0.7	4.4	231.8*	42.8	.830*
	1964	111.0*	95.7	10.7	26.7*	18.2	14.3*	3.4	12.4	3.2	19.1*	4.7	90.5	43.7	
Stellifer lanceolatus	1963	0.2	0.1	0.2	5.0	3.1	17.3	42.7	428.0*	24.7	20.8	14.0	8.7	48.5*	.210
	1964	0.5	0.8	0.8	5.1	6.4	16.8	81.3*	29.3	37.7	17.5	42.3*	8.3	17.8	
Arius felis	1963	0.6	0.1	12.9	22.3	41.9*	32.6	38.9	89.6*	86.6*	64.2	4.4	0.2	33.7	.452
	1964	0.0	0.0	40.9*	11.3	9.0	26.5	63.4*	58.9	51.4	56.9	87.7*	2.5	29.3	
Cynoscion arenarius	1963	1.6	0.3	1.7	6.3	19.6	39.1	60.5	50.2	22.7	22.7	22.9	16.0	22.5	.962*
	1964	0.1	0.5	0.7	2.3	33.7	85.7*	174.8*	101.9*	44.9*	26.4	27.6	21.5	37.4	
Anchoa mitchilli	1963	7.7	15.3*	13.8	26.9*	41.4	49.4*	15.0	14.8*	16.3*	48.0	39.1	19.4*	25.9*	.707*
	1964	4.6	4.8	11.9	12.4	34.6	8.0	8.0	2.9	4.8	32.5	40.9	9.7	13.2	
Total Fishes	1963	268.4	409.1*	395.9	592.4	981.0	731.0	746.1	1038.2*	314.2	293.8	242.8	602.3	556.5	.782*
	1964	244.8	249.9	365.3	650.7	1293.0*	1049.9*	1259.8*	685.7	466.6*	325.3	452.7*	603.5	583.0	

Table 11

Comparison of species composition (as % of total fishes) and catch (numbers per tow, N/T) in the 1963–1964 Galveston Bay trawl survey with results of other trawl surveys in the estuary. Only stations on similar sites were compared. GB = this survey; R = Reid (1957); J = Johnson (1973); GS = Gallaway and Strawn (1974); H = Henningsen (1977). Other information in Table 1.

Sub-areas	Zones	Dates		# of Stations		# of Tows		Species	% of Catch		Mean N/T	
EB	O,S	R	GB	R	GB	R	GB		R	GB	R	GB
		6/54	6/63	Var.	13	171	39	*M. undulatus*	33.7	63.7	111.1	141.1
		6/55	6/64					*A. mitchilli*	31.0	16.9	102.2	37.2
		6/56						*L. xanthurus*	17.0	13.4	55.9	25.6
								B. patronus	5.7	0.6	18.8	1.2
								C. arenarius	3.7	2.3	12.2	7.4
								A. felis	1.3	0.2	4.3	0.4
								All fishes			322.9	218.5
TB	O,S	J	GB	J	GB	J	GB		J	GB	J	GB
		1/70-	1/63-	13	12	718	444	*A. mitchilli*	38.2	24.4	119.1	42.0
		12/71	12/64					*M. undulatus*	27.7	58.3	54.4	94.0
								B. patronus	18.7	1.1	16.5	2.2
								L. xanthurus	2.8	4.4	1.5	7.6
								A. felis	2.6	3.1	3.0	3.4
								C. arenarius	1.8	2.2	5.4	3.8
								All fishes			217.8	161.6
UG	S	GS	GB	GS	GB	GS	GB		GS	GB	GS	GB
		1/68-	1/63-	11	2	257	75	*M. undulatus*	41.6	34.8	152.2	38.1
		12/69	12/64					*A. mitchilli*	29.1	25.8	106.5	28.2
								A. felis	15.6	19.2	57.3	21.0
								B. patronus	5.2	1.0	19.1	1.1
								P. octonemus	3.9	0.4	14.4	0.4
								C. arenarius	1.3	1.8	4.9	1.9
								L. xanthurus	1.1	0.6	4.0	7.2
								All fishes			366.2	109.6
GM	C,O	H	GB	H	GB	H	GB		H	GB	H	GB
		5/75-	1/63-	2	2	52	75	*M. undulatus*	64.7	19.2	126.7	15.2
		5/76	12/64					*Symphurus* spp.	11.2	7.7	21.9	6.1
								S. lanceolatus	8.9	22.9	17.3	18.1
								P. octonemus	8.0	2.8	15.6	2.2
								C. arenarius	2.4	22.7	4.8	17.9
								A. mitchilli	1.2	9.2	2.4	7.2
								All fishes			195.9	78.9

1963 and 1964, *M. undulatus* was relatively more abundant (63.7% of the fishes) and *A. mitchilli* was relatively less so (16.9%). Reid found higher catch rates for the total fish fauna and for all dominant fishes except *M. undulatus* than did the 1963–1964 survey. One of the factors that could have influenced the differing catches was sampling gear. Reid used several nets; included were a 3-m trawl with a 45-mm mesh body and either a 25-mm or a 10-mm mesh cod end and a 4.6-m net with a 38-mm mesh body and cod end or a 10-mm mesh cod end. Trawl-hauls were either of 10- or 30-min duration or 1 mile in length. In contrast, the 1963–1964 survey employed only a 3-m net with a 35-mm mesh body and 25-mm cod end towed for 5 minutes.

Johnson (1973) summarized surveys conducted from October 1969 through December 1971 that centered around the start-up of the Cedar Bayou power generating station in the San Jacinto River and Trinity Bay subareas (approximately 20 km northwest of Galveston). Compared with the 1963–1964 study, Johnson found relatively more *A. mitchilli* and *B. patronus* and relatively fewer *M. undulatus* on stations not impacted by the power plant. However, there were several differences in sampling methods which may have influenced catches. Johnson had more shore zone and fewer open water zone stations (10 and 3, respectively) than did the 1963–64 study (6 of each), and all of Johnson's shore stations centered on the effluent site while the earlier study sites fringed the whole subarea. Johnson also sampled only at night, employed a 5-mm mesh cod end, and sampled twice monthly for the complete period. The present survey was conducted during daylight, employed a net with a 25-mm cod end, and switched from twice monthly to monthly sampling after 14 months. Another factor that influenced catches was the existence in Johnson's survey of a warm-water plume (which attracted fishes and which did not exist earlier).

Gallaway and Strawn (1974) also studied the fishes near a power station discharge canal in the Upper Galveston Bay subarea, approximately 14 km west-northwest of Galveston, which began operating in 1966. Their trawl survey was conducted from January 1968 through December 1969 and, though they used a larger trawl (6.1-m) with a smaller mesh cod end (5-mm mesh liner) and sampled nine more stations only at night, their results were quite similar to those of the earlier survey (Table 11). In both studies, *M. undulatus* was the dominant fish and together with *A. mitchilli* and *A. felis* comprised over 75% of the fish catch in the Upper Galveston Bay shore zone. However, catch rates for the total fish fauna were three times higher in the later study and were 2–20 times higher for all major species (except *L. xanthurus* whose catch rate was slightly higher in the earlier study).

Henningsen (1977) conducted a trawl survey off the mouth of the Bolivar Roads Tidal Pass from May 1975 through May 1976. The fish fauna were quite dissimilar to that found in 1963–1964, both in the channel and open water zones, despite the use of a similar net and daytime sampling (Table 11). Henningsen found that *M. undulatus* comprised over 60% of the fishes in both areas. The 1963–1964 investigation found that only 18–20% of the catch was *M. undulatus* and that *S. lanceolatus, C. arenarius,* and *A. mitchilli* were relatively more abundant. Henningsen's overall catch rate was also 2.5 times that of the earlier survey.

The general lack of agreement on species composition and abundance between successive studies of the Galveston Bay estuary is in part due to different sampling methodologies. Other potential factors include short- and long-term fluctuations in actual species abundance linked to environmental fluctuations. For example, long-term studies of the Apalachicola estuary of northwest Florida have indicated that fluctuations in fish population sizes and species compositions may be linked to preceding or concurrent fluctuations in pollutants, local rainfall, river discharge, salinity, and temperature (Kobylinski and Sheridan 1979; Livingston 1977; Livingston *et al.* 1976). Such cycles can be seasonal, yearly, or even longer (5–7 years, Meeter *et al.* 1979). However, the possibility exists that, even with annual and areal variations in species composition and numerical catch rates, there may be a stable level of fish biomass supported by the estuary.

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